Microwave EUV light sources for photolithography

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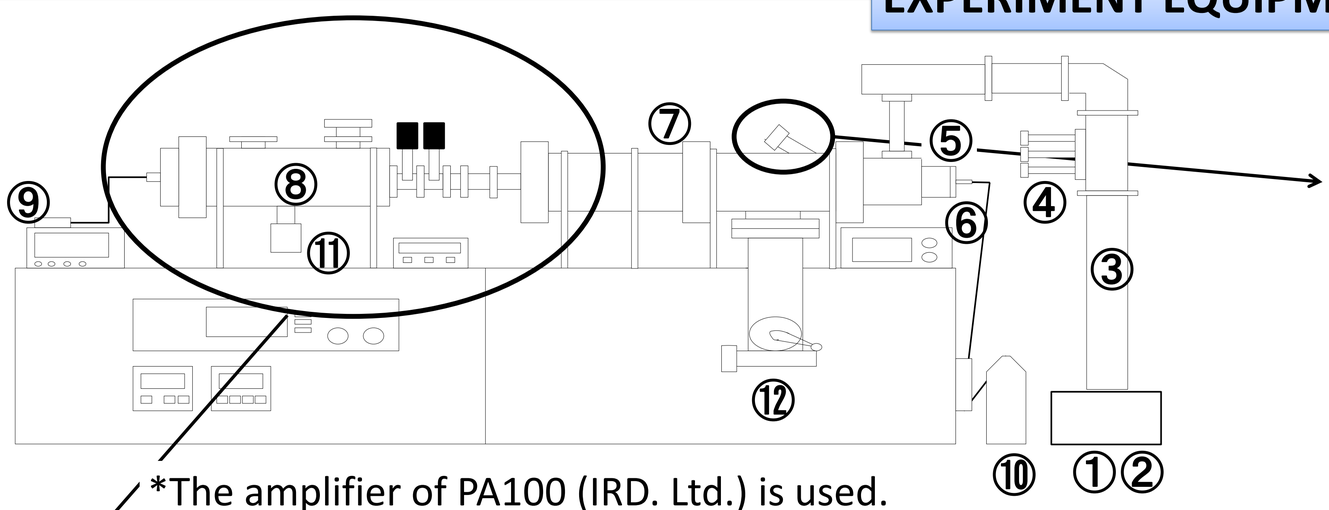
INTRODUCTION

The next generation of LSI integrated circuits utilizing EUV lithography is being eagerly developed, but the commercialization is behind schedule. There are still several problems to be resolved including the development of suitable EUV light sources.
There are two competing approaches for the development of the EUV source, namely, laser produced plasma (LPP) and discharge produced plasma (DPP). The proposed LPP sources using Tin as well as DPP sources utilizing electrodes produce 'Debris' which can contaminate the mirrors and the silicon wafers. The EUV power is not attained for the commercial requirement.
The new EUV source, i.e. the microwave discharge plasma production (MDPP) is invented in order to resolve those problems. The capillary quart tube is inserted in the center of the cavity which stores the microwave energy. The Xe gas which flows inside the tube absorbs the microwave to turn into the plasma, whose temperature is high enough to emit the EUV.

CONCLUSION

The MDPP has been proved to posses the high feasibility of the EUV light source for the next generation EUV lithography.
Up to several Watt EUV radiation has been successfully produced by the POC (Prof-of-Concept) experiment,
although magnetron output is 3kW, the repetition frequency is 100Hz and the duty is 10%.
The performance of the present facility is limited mainly by the magnetron power and the insufficient cooling system of the quart tube.

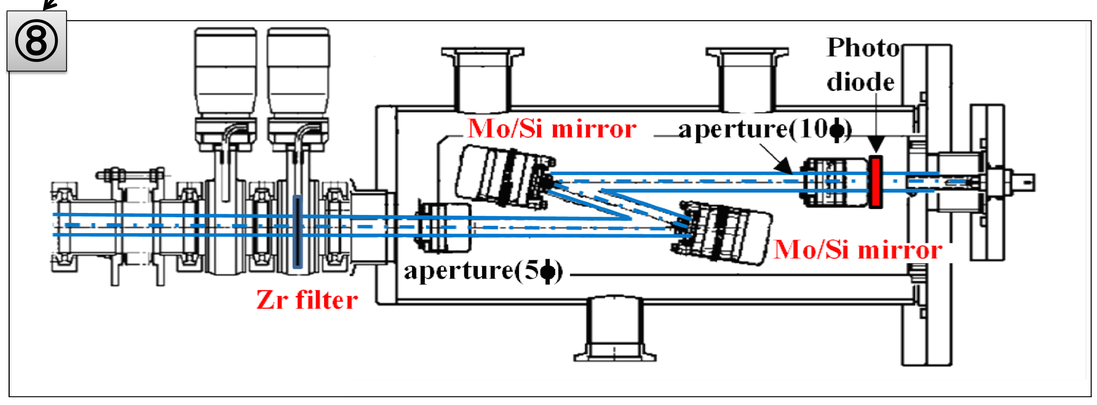
EXPERIMENT EQUIPMENT



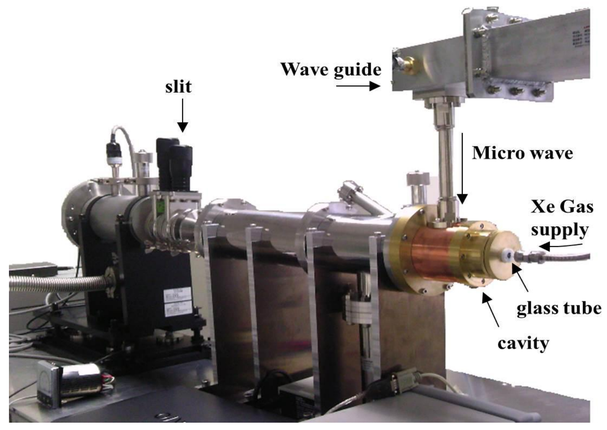
*The amplifier of PA100 (IRD. Ltd.) is used.

Visible light
From Xe plasma

①Magnetron
②Dual directional coupler
③Coaxial cable for wave guide
④Stab tuner
⑤Cavity
⑥Quarts tube
⑦Vacuum chamber
⑧Calorimeter
⑨Oscilloscope
⑩Xe gas cylinder
⑪ Rotary pump
⑫Turbo molecular pump



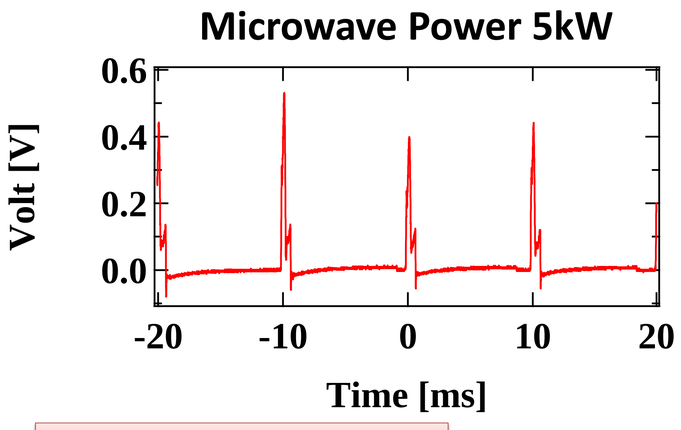
The reflection meter system, which consists of a Zr filter, two Mo/Si multi-layer reflection mirrors, apertures of ϕ5 and ϕ10, and a photo diode.



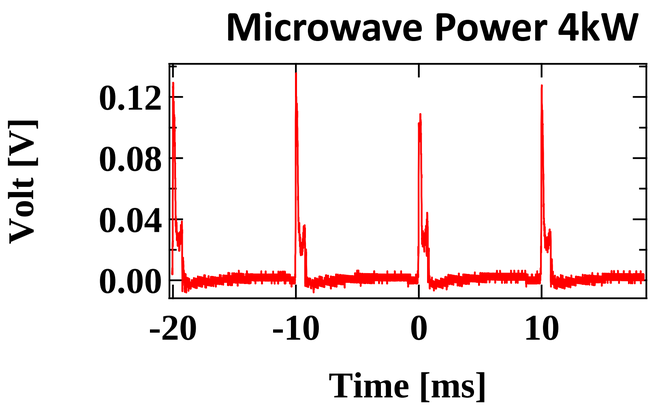
The 2.45 GHz magnetron source is rated at 6 kW.
The cylindrical cavity mode is TM110.

EXPERIMENT RESULTS

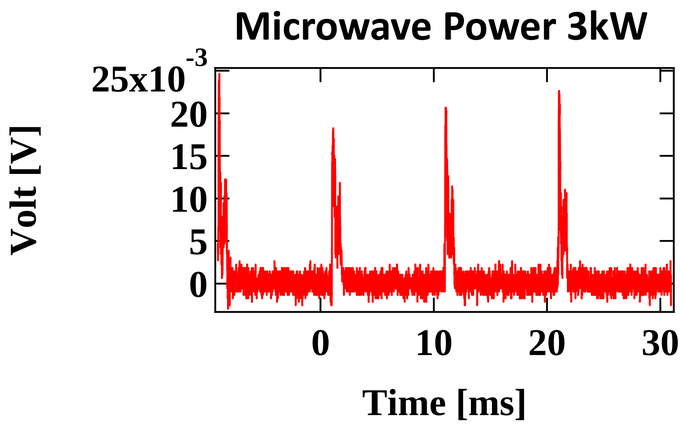
W_{EUV} = 2.7[W/2πstr]



W_{EUV} = 0.8 [W/2πstr]



W_{EUV} = 0.6 [W/2πstr]



Gas	Xe
Pressure	0.8~0.9Pa
Duty	10%
Pulse Repetition on Frequency	100Hz

$$W_{EUV}\,[W/2\pi str] = \frac{2\pi}{\Omega}\,\frac{\int_0^1 V\,dt}{R}\,\frac{1}{T_{zr}}\,\frac{1}{T_m}\,\frac{1}{\langle R_d R_m R_m \rangle}$$

The value <RmRmRd> was collimated by the comparison with the standard E-Mon.

Ω;Solid angle of reflection meter system (str)
V; output voltage of photodiode
R; Resistance in the amplifier
T_{Zr}; Transparency of Zr(Si_3N_4) filter (~0.12)
T_m; Transparency of filter(~0.36)
R_d; Responsivity of the diode (A/W)
R_m; Reflection ratio of EUV mirror (~0.6)